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The sensitivity of soil organic carbon pools to land management varies depending on former tillage practices

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Abstract

The rate of change in the relative size of SOC pools (sensitivity) due to land management may vary depending on their level of chemical and/or physical protection from decomposition, but has rarely been directly measured. The availability of archived (1975) soils from an abandoned long term tillage treatment experiment provided a unique opportunity to assess the sensitivity of SOC pools with different levels of stability to uniform land management after divergent tillage treatments. There were four initial treatments (1968-1991): 1) deep plough then no till, 2) shallow plough, 3) reduced till then rotary cultivation and 4) no till. The treatments were followed by uniform long-term grassland management (17 years) and subsequent short-term arable (two years). The sensitivity of SOC to land management was assessed by fractionation and direct comparison of archived soils and soils sampled in 2014 from this site. Both reductions and increases in SOC stocks were observed over time in comparable treatments but the overall effect was a trend towards an equilibration of SOC stocks across all plots. The labile fractions (particulate and dissolved organic matter) were sensitive to land management regardless of initial tillage treatment, but were more sensitive in the reduced till + rotary cultivation and no till treatments (2.3-5.3 times more sensitive than the whole soil) than the deep plough + no till and shallow plough treatments (1.1-2.2 times more sensitive than the whole soil). The chemically resistant fraction of the soils was surprisingly sensitive to land management (0.9-1.3 times more sensitive than the whole soil). This study shows that the degree of sensitivity of SOC fractions to land management can vary significantly depending on previous tillage management practices.

Abreviations:

DOC: dissolved organic carbon; ESM: equivalent soil mass, LUC: land-use change, NaOCl: sodium hypochlorite, POM: particulate organic matter; rSOC: chemically resistant soil organic carbon, SOC: soil organic carbon, SOM: soil organic matter, SPT: sodium polytungstate, S+A: sand and stable aggregates; s+c: silt and clay

1 Introduction

Land management practices do not affect all parts of soil equally and different soil organic carbon (SOC) pools may respond to land management practices or land-use change (LUC) at different rates (Zimmermann *et al*, 2007a). Although many studies report the changes in SOC stocks after LUC or due to land management, changes in the distribution of the total SOC stock between pools is rarely measured (Six *et al*, 1998; Don *et al*, 2009; O'Brien and Jastrow, 2013; Poeplau and Don, 2013; Duval *et al*, 2016).

Soil organic C pools may be defined functionally by the stability (resistance to loss) of SOC, with pools having distinct turnover rates (Zimmermann *et al*, 2007a). SOC stability is determined by its physical and chemical properties; three mechanisms have been identified which determine SOM stability: 1) occlusion within soil aggregates (von Lützow *et al*, 2006); 2) physico-chemical protection through association with soil minerals (Schrumpf *et al*, 2013), and 3) inherent chemical recalcitrance (Kleber, 2010). The sensitivity of a SOC pool is the rate at which its SOC stock changes relative to the whole SOC stock. Changes in the relative distribution of SOC between pools caused by LUC or land management practices can be used as a measure of SOC sensitivity (John *et al*, 2005). Intuitively, it would be expected that the level of SOC stability within a pool would influence its sensitivity, with the most stable pool being least sensitive. Studying changes in total SOC stocks should be accompanied by a measurement of SOC stability and an assessment of SOC pool sensitivity to provide a better understanding of the changes in C dynamics (John *et al*, 2005).

Changes in SOC stocks after changes in land use and management take place very slowly (years, where there is no erosion) (Simonsson *et al*, 2014; Stockmann et al., 2013), thus the majority of studies that record changes in SOC stocks after changes in land use or management use paired plots (Poeplau and Don, 2013) or chronosequences (O'Brien and Jastrow, 2013). However, studies that substitute space for time have inherent uncertainties associated with the spatial heterogeneity of soil and potential differences in the physical, chemical and climatic conditions of the plots prior to the change in land use (Poeplau and Don, 2013).

There has been much debate over the potential for no tillage and reduced tillage to increase SOM contents. Meta-data analysis has suggested that no-till farming can result in overall increases in SOC in the surface soil compared to deep inversion tillage, however, when considering the whole soil profile, no-till has limited effects on SOC stocks (Stockmann *et al*, 2013). Recent experimental evidence regarding the impact of no tillage and reduced tillage systems on SOC contents suggests that the distribution of SOC through the profile changes rather than the overall SOC content (Hermle *et al*, 2008; Powlson *et al*, 2011, 2014). Increasing attention is being given to SOC storage in agricultural systems under the recent 'four per 1000' initiative (Poulton *et al*, 2018). Further investigations of changes in SOC pools resulting from land management practices such as tillage are needed to increase our understanding of agricultural SOC dynamics and stabilisation processes.

The abandonment of a former long-term tillage treatment experiment (1968 to 1991) provided a unique opportunity to assess changes in SOC stocks and SOC sensitivity to land management after long-term application of tillage treatments (deep plough + no till, shallow plough, reduced till + rotary cultivation and no till), followed by long-term uniform management as grassland and short-term return to arable. The site was resampled in 2014 with the aim of quantifying how current SOC stability has changed compared to archived soil sampled from 1975, and the sensitivity of SOC pools to the land management over this time frame. It was hypothesised that the physically unprotected, low stability pools would be more sensitive (have the greatest change in SOC stock) and the more stable, physically protected pools would be least sensitive.

2 Methods

2.1 Tillage treatments

The long term tillage treatment experiment at South Road, near Edinburgh, (55°51'24"N 3°10'55"W) began in 1967, examining crop and soil responses to contrasting tillage treatments for continuous spring barley production. The soil is derived from Carboniferous sediments and contains coal fragments (Ball *et al*, 1996). There were four replicates of each tillage treatment located on poorly drained Gleysol which is a Winton/Macmerry complex (loam to sandy clay loam topsoil, clay loam subsoil) and four on freely drained Macmerry (Ball *et al*, 1989). Here we only consider the Gleysol replicates as these plots could be re-located with more certainty and there were more of the archived samples available for the Gleysol plots. The tillage treatments were applied to 12 x 48 m plots as described in Ball *et al* (1996) and were 1) deep plough: inversion tillage to 35 cm from 1968–1983, then no till from 1983–1991; 2) shallow plough: inversion tillage to 20 cm from 1968–1991; 3) reduced till: non-inversion chisel plough to 30 cm from 1968–1983, then broadcast and rotary tillage to 5 cm from 1983–1991 and 4) no till: direct drill - seeds sown direct with no ploughing from 1968–1991.The field was sown with spring barley from 1968–1983, after which it was sown with winter barley until 1991, except 1989 when the crop was oil-seed rape. The experiment was terminated in 1992. In 1996 the field was ploughed to 20 cm and sown with grass, in autumn 2013 and autumn 2014 the field was ploughed to 30 cm and sown with winter wheat. The site has an annual average rainfall of 980 mm and an annual average temperature of ~8 °C (averaged from 1981 to 2010, Met Office, 2016).

2.2 Soil sampling

In 1975 samples were collected from all plots for the 0–36 cm depth interval in 6 cm increments. Samples were collected using an auger and replicate plots for each treatment were bulked by depth to give a composite sample for each treatment-depth combination. The soil was sieved to < 4 mm, air dried, sealed in plastic bags within tins and archived in a cool, dry shed.

In August 2014, the plots were relocated using detailed experimental field plans, soil survey maps (Pidgeon, 1980) and aerial photographs of the site. Soil was sampled to 36 cm using an auger (10 times per plot), and then split into 6 cm depth increments using a ruler and a sharp knife. Soils were bulked across replicate plots, as was done in 1975, and sieved to 4 mm. Soils which were bulked were mixed thoroughly during sieving to remove the heterogeneity between replicate plots. Bulk density samples from 3 depths (0-5 cm, 18-23 cm and 30-35 cm, n= 4 per plot) were determined by the core method using a hammer driven core (Elliott *et al*, 1999).

2.3 Effect of long term soil storage

To ascertain whether there was a significant loss of SOM from archived soils, all archived soils were analysed by loss on ignition and compared to measurements made in 1975. Three 10 g sub-samples in pre-weighed tin cups were placed into a muffle furnace. The temperature was gradually increased to 550 °C and left for six hours. Samples were re-weighed and OM concentrations were calculated from the loss in mass (Howard and Howard, 1990).

2.4 Fractionation

Preliminary analyses of hot-water extractable fractions (following the method by Ghani et al., 2003) from the soil sampled in 2014 suggested that the greatest differences in C stability would be found at depths of 0–6, 18–24 and 30–36 cm (Miller, 2016). For these three depth intervals, three 30g sub-samples from each composite soil were fractionated using the method described in Zimmermann *et al* (2007a,b) which isolates five fractions. Deionised water (161 ml) was added to each 30 g sub-sample in a 250 ml glass beaker and was dispersed by sonication using a calibrated Soniprep 150 plus ultrasonic disintegrator (MSE (UK) Ltd, London) with an output energy of 1500 J g^{-1}, The soil was then wet sieved through a 64 µm sieve using a pressurised sprayer. The water and material passing through the sieve was captured and transferred into a 2 l bottle. The volume of the water was recorded and the material left in the sieve was transferred into a pre-weighed mesh bag (pore size 60 µm) in a 40 °C oven to dry.

Once dry, the mesh bag was re-weighed and the material was transferred into a centrifuge bottle along with 90 ml of sodium polytungstate (SPT) solution at a density of 1.80 g cm^{-3}. The particulate organic matter (POM) fraction was then isolated by centrifugation for 45 minutes at ~5000 x g to accelerate sedimentation of heavy particles. After centrifugation, the supernatant was siphoned off using a vacuum pump, vacuum flask, a pipette and 6 mm tubing. The floating material was removed from the SPT by passing the solution through a vacuum filtration unit (Millipore, Hertfordshire, UK) with a nylon Whatman filter paper (5 µm, 90 mm diameter), the material left on the filter paper was the

POM. The sediment remaining in the centrifuge bottle was the sand and stable aggregate (S+A) fraction.

The water retained from wet sieving was decanted into pre-weighed 250 ml centrifuge bottles and centrifuged for 15 minutes at ~3500 x g. The supernatant was retained, and the centrifuge step was repeated until all of the water had been centrifuged. The centrifuge bottle was dried at 40 °C and re-weighed, giving the mass of silt and clay. To quantify any silt and clay still suspended in the retained supernatant, a sub-sample was filtered through a pre-weighed Whatman nylon filter (0.45 µm pore size). The filter paper was dried (at 40°C) and re-weighed, the mass of material per ml of water was then calculated and added to the mass of silt and clay in the centrifuge bottle. The filtered supernatant sub-sample was retained to determine dissolved organic C (DOC) content using a Rosemount-Dohrmann DC80 total C analyser (Rosemount Analytical, Santa Clara, CA).

The silt and clay contains a chemically resistant (rSOC) fraction which was quantified by chemical oxidation of the silt and clay. A 6% sodium hypochlorite (NaOCl) solution was allowed to react with a 1 g subsample of the silt and clay for 18 hours in a pre-weighed centrifuge tube. The samples were rinsed using deionised water and dried in a 40 °C oven. The oxidation reaction was repeated twice, after which the centrifuge tube was dried and re-weighed. The percentage of the silt and clay which reacted is the silt and clay (s+c) fraction, and the remainder is the rSOC fraction.

This fractionation method was chosen as it was tested for its ability to isolate fractions which are modelable (Zimmermann *et al,* 2007a,b). These fractions were shown to correspond to the five conceptual SOM pools in the RothC model (Coleman and Jenkinson, 2014). To initialise the RothC model, the isolated fraction SOM pools can be divided between conceptual pools based on splitting ratios calculated by Zimmermann *et al* (2007a,b) (Table 1). Each conceptual pool has a decomposition rate constant (Table 1) which is modified depending on site specific factor (e.g. temperature and moisture content, Coleman and Jenkinson, 2014).

2.5 C analyses

Whole soil and solid fraction sub-samples (n=3) from 1975 and 2014 soils were ball milled and analysed for C concentration using a Flash 2000 elemental analyser (Thermo Scientific, Waltham, MA, USA). DOC sub-samples (~10 ml, n=3) were acidified with two drops of orthophosphoric acid, sparged with N_2 for two minutes to remove any carbonates and then analysed for DOC using a Rosemount-Dohrmann DC80 total C analyser (Rosemount-Dohrmann Analytical Inc., Santa Clara, CA). To correct the 2014 SOC stocks for changes in the bulk density caused by land management practices, an equivalent soil mass (ESM) approach was used. ESM was calculated using the mass of soil per unit area for each depth in 1975 as a reference, following the calculations outlined in Lee *et al* (2009). Percentage organic matter contents were estimated by multiplying % OC by a conversion factor of 1.724 (Nelson and Sommers, 1996).

2.6 Statistical analyses

All statistical analyses were carried out in Genstat (Version 15.1, VSN International, 2011). Within year variability was determined by two-way ANOVA and variability between years was determined by paired t-test. Significant differences were determined at $p < 0.05$. Post-hoc multiple comparison tests were applied to distinguish between means of different treatments. The sensitivity of isolated SOM fractions was assessed by linear regression of the relative changes (%) in the SOC stock stored in each fraction and the ESM SOC stock between 1975 and 2014 (following Poeplau and Don, 2013).

3 Results

3.1 Loss of organic matter during long term storage

Re-measuring loss on ignition of archived soils and comparing to measurements made in 1975 showed similar organic matter contents (~90–110%) to those measured in 1975 (Table 2). The exception was deep plough at 30–36 cm which appeared to have lost ~35% of the 1975 value (Table 2).

3.2 Total SOC stocks and distribution of SOC between fractions

Across the whole profile the deep plough + no till treatment ESM SOC stock increased by 8.0% from 1975 to 2014 (from 125 ± 6.4 to 136 ± 1.3 tC ha^{-1}). However, the ESM SOC stock below 24 cm declined to significantly lower than in 1975 and lower than all other treatments ($p < 0.001$) (Figure 1). The shallow plough treatment declined by 13.3% (from 190 ± 4.9 to 168 ± 1 tC ha^{-1}) with the greatest loss below 30 cm ($p < 0.001$) (Figure 1). The reduced till + rotary cultivation treatment increased by 10.8% (from 154 ± 3.8 to 173 ± 4.7 tC ha^{-1}) with the greatest increases below18 cm ($p < 0.01$) (Figure 1). The no till treatment (30 – 36 cm depth missing from 1975 samples) increased by 16.9% (from 136 ± 3.9 to 164 ± 3.2 tC ha^{-1}) with significant increases below 12 cm ($p < 0.01$) (Figure 1).

The proportion of total soil SOC stock stored within isolated SOM fractions in 1975 and 2014 are shown in Figure 2. There were significantly lower proportions of C stored in the S+A fraction of all treatments in 2014 compared to 1975 from 18–24 cm ($p < 0.01$) (Figure 2). Within the shallow plough treatment from 30–36 cm there were significantly lower proportions of total SOC stock C contained within the rSOC, POM and DOC fractions in 2014 (16.0 ± 1.6, 22.6 ± 5.6 and 1.9 ± 0.5% decreases, respectively) (Figure 2).

3.3 Whole soil and SOM fraction C:N ratios

Whole soil C:N ratios at different depths remained fairly stable between treatments within years, although C:N ratios were generally lower in 2014 than 1975 (Figure 3). The C:N ratio of the S+A fractions (see Table in supplementary information) showed a trend between years similar to that of the SOC distribution. The S+A fractions had significantly higher C:N ratios in 1975 than in 2014. The s+c fractions generally had a significantly higher C:N ratio in 2014, suggesting the OM was less decomposed. Many of the rSOC fraction sub-samples had N concentrations that were below the detection limit of the elemental analyser. Therefore calculation of C:N ratios was not possible. Where comparisons between years were possible, C:N ratios were significantly higher in 2014 compared to 1975 (see supplementary information for fraction CN values).

3.4 Sensitivity of SOC fractions to land management

The sensitivity of isolated SOM fractions was indicated by the slope of the regression line between relative changes in ESM SOC stock and fraction C stock (Table 3, Figure 4). A greater slope indicates a greater rate of change in the fraction SOC stock relative to the whole soil due to the land management, and indicates that there is a greater proportion of total SOC stored in that fraction.

Sensitivity followed the order POM > DOC > rSOC for all tillage treatments. Significant correlations ($p < 0.05$) were found between % changes in ESM SOC stocks between 1975 and 2014 for all isolated fractions except for the DOC fraction in the deep plough + no till treatment (Table 3). The POM fraction was consistently more sensitive than the total SOC (the slope of the regression line is > 1) concurrent with large proportional changes in the C stored in this fraction (Table 3, Figure 4). The labile POM and DOC fractions were most sensitive in the reduced till + rotary cultivation and no till treatments – slopes of 5.3 (reduced till + rotary cultivation) and 3.8 (no till) for POM, and 2.3 (reduced till + rotary cultivation) and 2.8 (no till) for DOC (Table 3). The s+c fraction only had a significant correlation between total SOC stock change and fraction C stock change in the shallow plough treatment, where the slope was -1.33 (R^2 =0.53, $p < 0.05$) (Table 3).

The rSOC fraction was slightly more sensitive than the whole soil (slope ranged from 1.1–1.3) in all treatments except the deep plough + no till treatment which was slightly less sensitive (slope of 0.9), and was particularly sensitive in the no till treatment (slope 1.39) (Table 3). The rSOC fraction was more sensitive than the s+c which generally had a negative correlation to % ESM SOC stock change (Table 3, Figure 4), although the relationship was only significant for the shallow plough treatment (Table 3).

4 Discussion

4.1 ESM SOC stocks

The SOC stocks of inversion and non-inversion tillage treatments often changed in opposite directions e.g. decreases in SOC stocks at depths below 24 cm in inversion tillage plots were mirrored by increases in the corresponding depth in the non-inversion tillage treatments. The overall effect was a trend towards equilibration of SOC stocks across the field. Subsoil SOC stocks have been observed to be higher under cultivation than permanent grassland due to direct fresh C inputs to this layer through incorporation of residues (Poeplau and Don, 2013; Rasse *et al*, 2006; Huggins *et al*, 2007, and Don *et al*, 2009). After cessation of tillage, the deep plough + no till and shallow plough treatments accumulated C down to 24 cm, with sharp decreases below this depth likely due to the loss of direct inputs of fresh C after the cessation of inversion tillage.

The tillage operations at the site in 2013 and 2014 may have caused some SOC losses which are impossible to quantify. Conant *et al* (2007) estimated that one tillage event in a no till agricultural system could lead to losses of between 1 and 11% of SOC stock, suggesting that the grassland in this study may have lost a significant amount of C due to tillage disturbance prior to sampling. However, despite the uniform land management of the site from 1992 to 2014 the effects of the divergent tillage treatments were still evident in the total SOC stocks and the isolated SOM fractions.

4.2 Distribution and sensitivity of isolated fractions

The labile POM and DOC fractions were found to be most sensitive with the degree of sensitivity varying between soils which had previously been under different tillage treatments. POM has been identified as the most sensitive fraction to LUC (Conant *et al*, 2004, Franzluebbers *et al*, 2002; Poeplau and Don, 2013; Plaza-Bonilla *et al*, 2014), likely due to rapid accumulation of this fraction under low impact systems such as permanent grassland (Poeplau and Don, 2013) and is rapidly lost due to cultivation (Camberdella and Elliott, 1992). However, POM is spatially variable and may not be a good indicator of SOC stock changes (Burke *et al*, 1999; Leifeld and Kögel-Knabner, 2005; Don *et al*, 2009;

Simonsson *et al*, 2014). Utilisation of composite samples in the present study obliterated any spatial differences in C distribution to fractions between treatment plots. The wide variation of C:N ratio in the 2014 POM samples is most likely due to the presence of coal fragments present in this carboniferous soil (Ball *et al,* 1996).

The chemically resistant rSOC fraction was surprisingly sensitive, particularly in the no till treatment, indicating that this fraction was become a relatively more important C pool through time. Indeed, it was more sensitive than the s+c fraction which is considered to be an active C pool (Leifeld and Kögel-Knabner, 2005; Zimmermann *et al*, 2007c). Previous studies have found the rSOC fraction to be sensitive to LUC (Spohn and Giani, 2011; Poeplau and Don, 2013). This supports a theory that the rSOC fraction is only inert under steady state conditions (Poeplau and Don, 2013) questioning the existence of, or the ability of fractionation methods to isolate, an inert SOM fraction (Rethemeyer *et al*, 2004; Poeplau and Don, 2013).

A decrease in the C:N ratio of the S+A fraction from 1975 to 2014 coupled with an increase in the relative mass of soil contained within this fraction suggests that the C in this fraction is more stable in 2014 than in 1975 (Conen *et al*, 2007), although the SOC stock within this fraction had declined. Conen *et al* (2007) found that the C:N ratio of mineral associated organic matter decreased with soil depth whilst stability, as determined by radiocarbon dating, increased. The formation of the small but highly stable aggregates isolated in the S+A fraction is encouraged by the presence of root mats in grassland soil. Conversely, the C:N ratio of the s+c fraction increased from 1975 to 2014, suggesting an accumulation of less decomposed material. Indeed, SOC stocks increased in this fraction. This suggests that fresh OM was preferentially being adsorbed onto minerals rather than being physically protected in micro-aggregates. This supports the theory that occlusion within stable micro-aggregates is a secondary process initiated by adsorption of OM on to mineral surfaces (Lehmann *et al*, 2007). Cessation of tillage allows the prolonged formation of macro-aggregates (Six *et al*, 2000; John *et al*, 2005; O'Brien and Jastrow, 2013). However, there is expected to be a lag between an improvement in aggregation and the formation of more stable micro-aggregates which are isolated in the S+A fraction (DeGryze *et al*, 2004, O'Brien and Jastrow, 2013). It is also possible that a portion of this fraction may have been lost during the subsequent tillage of the site.

5 Conclusions

Differences in Labile fractions were found to be the most sensitive to the management histories of the plots at this site. The rSOC fraction was also found to be significantly sensitive and more sensitive than the mineral bound s+c and S+A fractions. However, the degree of sensitivity of each fraction can vary significantly even between different tillage management systems. This study took advantage of a unique opportunity to study the long term effects of different tillage practices on SOC stability. More studies like the one presented here are required on a wide variety of soil textures and different land uses and management practices to establish general principles for estimating changes in SOC stability and increase our understanding of soil C dynamics and storage.

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Figure 1: Equivalent soil mass (ESM) SOC stocks of a) deep plough + no till, b) shallow plough, c) reduced till + rotary cultivation, and d) no till treatment plots in 1975 and in 2014, 22 years after tillage treatments were ceased. Stars denote significant differences between years, paired t-test * <0.05, ** <0.01, *** < 0.001.

Figure 2: Percentage of whole soil total C contained within isolated fractions in 1975 and 2014 (row a) POM, b) DOC c) rSOC, d) s+c, and e) S+A). DP – deep plough + no till, SP – shallow plough, RT – reduced till + rotary cultivation and NT – no till. An asterix (*) between 1975 and 2014 values at any depth denotes a significant difference between the two years (paired t-test, $p < 0.05$)

Figure 3: Average C:N ratios for whole soil in 1975 and 2014 for a) deep plough + no till, b) Shallow plough, c) reduced till + rotary cultivation, and d) no till treatment plots * denotes values which are significantly higher than the corresponding value in the other year (paired t-test, $p < 0.05$). Stars denote significant differences between years, paired t-test * <0.05, ** <0.01, *** < 0.001.

Figure 4: Sensitivity of isolated SOM fractions to a change in land-use from different tillage treatments to grassland. Fractions were a) POM, b) DOC, c) rSOC, d) s+c and e) S+A. The greater the slope of the regression line, the more sensitive the fraction.

Table 1: Decomposition rate constants for conceptual soil organic matter (SOM) pools in the RothC model (Coleman and Jenkinson, 2014) and isolated SOM fraction splitting ratios calculated by Zimmermann *et al* (2007a) for a range of soils, standard deviations are given in parenthesis. POM: particulate organic matter; DOC: dissolved organic matter; s+c: silt and clay; S+A: sand and stable aggregates; rSOC: chemically resistant soil organic carbon.

<table>
<tr><th>RothC
Conceptual SOM pool</th><th>Decomposition rate
constant (t C ha^{-1} yr^{-1})</th><th>Isolated fraction
SOM pools</th><th>SOM spliting
ratio</th></tr>
<tr><td>Resistant plant material</td><td>0.3</td><td rowspan="2">POM + DOC</td><td rowspan="2">0.1119 (0.0382)</td></tr>
<tr><td>Decomposable plant material</td><td>10</td></tr>
<tr><td>Microbial biomass</td><td>0.66</td><td rowspan="2">s+c + S+A</td><td rowspan="2">0.0260 (0.0004)</td></tr>
<tr><td>Humified organic matter</td><td>0.02</td></tr>
<tr><td>Inert organic matter</td><td>0</td><td>rSOC</td><td>1</td></tr>
</table>

Table 2: Changes in concentration of organic matter (OM) from archived soils in storage. OM was estimated by applying a conversion factor of 1.724 to measured organic C concentrations. Standard error of the means (SEMs) are in parenthesis. Note there was only one measurement in 1975 so no SEMs could be calculated.

Treatment	Depth (cm)	Archived soil OM measured 1975 (% w/w)	Archived soil OM measured 2014 (% w/w)	Potential OM change In storage (%)
Deep plough + no till	0–6	4.41	4.47 (0.09)	1.2 (2.1)
	18–24	4.72	4.53 (0.14)	-4.4 (3.2)
	30–36	4.35	3.24 (0.13)	-34.8 (5.7)
Shallow plough	0 - 6	5.25	5.88 (0.19)	10.6 (2.8)
	18 - 24	6.18	5.69 (0.16)	-8.8 (3.1)
	30 - 36	5.25	4.84 (0.07)	-8.6 (1.6)
Reduced till + rotary cultivation	0–6	5.79	5.73 (0.03)	-1.0 (0.6)
	18–24	5.02	5.25 (0.07)	4.3 (1.3)
	30–36	2	1.9 (0.05)	-5.5 (2.7)
No till	0–6	5.69	5.85 (0.42)	1.7 (6.8)
	18–24	3.3	3.63 (0.23)	8.3 (6.1)

Table 3: Regression equations, R^2 values and significance level of the relative (%) change in equivalent soil mass SOC stocks in deep plough + no till, shallow plough, reduced till + rotary cultivation and no till treatments against the relative change in the proportion of SOC stock stored in organic matter fractions. POM, DOC, rSOC, s+c and rSOC, s+c and S+A as a measure of fraction sensitivity to land-use change. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns – not significant.

		Fraction					
		POM	DOC	rSOC	s+c and rSOC	s+c	S+A
All Treatments	Regression	y = 3.37x	y = 2.02x	y = 1.18x	y = 0.64x	y = -0.46x	y = 0.28x
	R^2	0.73	0.67	0.79	0.72	0.18	0.09
	Significance	***	***	***	***	*	ns
Deep plough + no till	Regression	y = 1.96x	y = 1.06x	y = 0.94x	y = 0.76x	y = 0.34x	y = 0.54x
	R^2	0.63	0.33	0.75	0.86	0.12	0.38
	Significance	*	ns	*	***	ns	ns
Shallow plough	Regression	y = 2.16x	y = 1.83x	y = 1.11x	y = 0.72x	y = -1.33x	y = 0.40x
	R^2	0.55	0.7	0.95	0.66	0.53	0.29
	Significance	*	**	***	**	*	ns
reduced till + rotary cultivation	Regression	y = 5.31x	y = 2.32x	y = 1.10x	y = 0.48x	y = -0.39x	y = 0.50x
	R^2	0.82	0.55	0.61	0.28	0.28	0.11
	Significance	***	*	*	ns	ns	ns
No till	Regression	y = 3.76x	y = 2.78x	y = 1.34x	y = 0.63x	y = -0.37x	y = -0.62x
	R^2	0.88	0.93	0.77	0.94	0.3	0.59
	Significance	**	**	*	**	ns	ns